

[Increased accuracy has been obtained in the recent experiments made with the hydrogen lamp, hereafter described, in the test chamber by the removal of a small part of the mixing flap (see fig. 3). This renders it possible to place the lighted safety-lamp in the chamber before the gas is introduced and mixed with the air; since it enables the flap to be swung within the chamber without touching the lamp. Accordingly the test is commenced by placing the lamp in position close to the glass front; the chamber is then closed, the measured volume of gas is introduced and mixed with the air by moving the flap, and the "cap" is observed, and its appearance noted as soon as it undergoes no further change. The chamber is only opened finally when the lamp is to be removed. Any slight alteration in the gaseous mixture, which was formerly caused by the subsequent introduction of the lamp, is thus avoided.—March 26, 1892.]

II. "On the Application of a Hydrogen Flame in an ordinary Safety-lamp to the Detection and Measurement of Fire-damp." By FRANK CLOWES, D.Sc. (Lond.), Professor of Chemistry, University College, Nottingham. Communicated by Professor ARMSTRONG, F.R.S. Received March 24, 1892.

In a former paper ('Roy. Soc. Proc.,' vol. 50, p. 122) an apparatus was described in which the appearance of the "cap" over the flame of a safety-lamp could be observed and measured when the lamp was exposed to definite mixtures of air with methane or firedamp. The relative sensitiveness of different forms of lamp, and of different flames, when they are applied to the detection and measurement of "gas," was thus readily ascertained. It was stated that the flames of colza oil, rape oil, mixed oils, benzoline, methylated spirit, and hydrogen had been experimented upon: and that the non-luminous flames producible by benzoline, alcohol, and hydrogen far excelled the more or less luminous oil flames in their power of indicating low percentages of inflammable gas or vapour in the air. It was further found that the delicacy of the test was much increased by grinding the inner surface of the back of the glass cylinder of the lamp so as to destroy its reflecting power.

Ashworth's modified benzoline safety-lamp was especially referred to as an efficient lamp both for lighting and for gas-testing. The brilliant illuminating flame gave a forward light equal to one miner's candle. When it was reduced in size by drawing down the wick it became blue and non-luminous: and when it was viewed in this condition against the ground glass surface, or, better still, against the dead-black background produced by smoking the interior of the

lamp glass at the back, a distinct flame cap, 7 mm. in height, was seen in air containing only 0·5 per cent. of methane or fire-damp. The height, density, and definition of the cap over this flame were found to increase pretty regularly as the percentage of "gas" in the air was augmented. The efficiency of this lamp for lighting and testing is thus placed beyond doubt.

In continuing the experiments described in the former paper, however, a comparison of the "caps" produced by the flame of this lamp with those produced by a small alcohol flame and a small hydrogen flame showed that the latter flames were more sensitive as gas indicators than that of the benzoline lamp. Thus, when an alcohol and hydrogen flame, each 10 mm. in height, were introduced, together with the small blue benzoline flame, into the testing chamber, which was filled with air containing 1 per cent. of coal gas, flame caps of the following dimensions were obtained:—

Hydrogen.....	27	mm.
Alcohol.....	19	„
Benzoline.....	7·2	„

It is true that the benzoline flame employed in this experiment was much smaller than the two other competing flames. But it must be remembered that the benzoline flame is *necessarily* small when it is employed for gas-testing, since, if its dimensions are increased, it becomes luminous, and renders the pale "cap" invisible. And one of the principal advantages of the alcohol and hydrogen flames consists in their remaining non-luminous, even when they are made of large dimensions; the greater surface and higher temperature of their larger flames producing, therefore, much larger and more visible "caps" than is possible with a small benzoline flame.

It will be seen from the results of the experiment just described that the hydrogen flame has the advantage over the alcohol flame in the dimensions of the "cap" which it yields. But by prolonging the test, another advantage of the hydrogen flame over its rival was ascertained. The two flames were allowed to burn side by side in the chamber, charged with air containing 1 per cent. of coal gas, for over thirty minutes. Throughout this protracted test both the hydrogen flame and the "cap" above it remained unaltered in size and appearance. The alcohol flame and its "cap," however, steadily diminished in size: after five minutes the height of the cap had fallen from 19 mm. to 12·5 mm., and after another interval of five minutes the height of the cap was reduced to 6·5 mm.: and thirty minutes after the beginning of the experiment the flame was spontaneously extinguished. This result seems to indicate that the alcohol flame is much more sensitive to the influence of the presence of products of combustion, and to deficiency of oxygen, than the hydrogen flame

is: the difference is possibly due to the much smaller quantity of oxygen required by the hydrogen flame for its combustion.

*Alcohol Lamps.*—The possibility of producing large and distinct “caps” when testing by means of an alcohol flame for low percentages of “gas” in air was taken advantage of by G. Pieler in 1883 to produce the most sensitive form of safety-lamp for gas-testing yet invented. The Pieler lamp is a large Davy lamp, burning alcohol from a circular wick, which yields a large flame, 30 mm. in height. When the lamp is used for testing, even the feeble light of this flame is shielded from the eye, so as not to interfere with the perception of the “cap.” Experiments with this lamp in known percentage proportions of “gas” and air have been described by several observers, and their results were fully confirmed by a series carried out in the test-chamber. The “caps” obtained were as follows:—

0.25 per cent. of methane gave a 30 mm. cap.	
0.5                    “                    “                    “                    “	65                    “
0.75                   “                   “                   “                   “	75                   “
1.00                   “                   “                   “                   “	90                   “

Indeed the flame of this lamp is so sensitive that when the proportion of methane in the air reaches 1.75 per cent. the “cap” touches the top of the gauze of the lamp; and with a somewhat higher percentage of “gas,” the enlarged “cap” completely fills the interior of the gauze.

Practical men, who have used this lamp, seem to feel some doubt as to its perfect safety in the mine. But their main objection is that the alcohol flame is non-luminous, and accordingly a second lamp must be carried for lighting purposes when the Pieler lamp is employed for gas-testing.

Attempts have been made to obviate the inconvenience of carrying two lamps, by constructing a safety-lamp with two reservoirs. One of these would contain oil, and the other alcohol. Each would be supplied with a wick in the ordinary way. By raising or lowering one wick or the other, a luminous oil-flame for lighting purposes, or a non-luminous alcohol-flame for gas-testing, should thus be obtained at will within one and the same lamp: the flame being passed from one wick to the other, as may be required. Practical difficulties arose in the use of this composite lamp, which have prevented its adoption.

*Hydrogen Lamps.*—Pieler was aware of the advantage secured by employing a hydrogen flame for gas-testing. Owing to the difficulty, however, of adapting a hydrogen supply to a portable safety-lamp, he recommended that samples of air from the mine should be brought to the surface, and tested by a hydrogen flame burning from a

chemical generator, the apparatus being a fixture in a testing room situated near the pit's mouth.

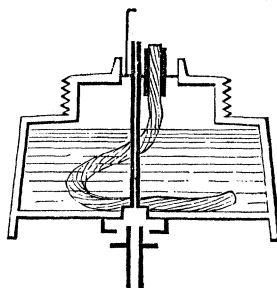
Since, however, hydrogen gas is now obtainable at small cost, compressed in light steel cylinders, it has been found possible to furnish a supply of the gas to a jet inclosed in an ordinary safety-lamp.

The lamp is so constructed that oil or benzoline may be burnt in the ordinary way, from a wick when the lamp is to be used for lighting purposes, the wick being drawn down so as to produce a non-luminous flame, and this yielding caps in gas-testing when proportions of gas exceeding 3 per cent. have to be looked for. When proportions of gas less than 3 per cent. are to be looked for and estimated, the hydrogen gas is introduced by a metal jet fixed close to the wick; the gas at once kindles. The wick is then drawn down until the oil flame is extinguished, and the cap is looked for over the hydrogen flame. A cap is easily seen over this hydrogen flame when only 0.25 per cent. of gas is present. When the illuminating flame is required the wick is again pushed up, and kindled by the hydrogen flame. The supply of hydrogen may then be withdrawn. The oil flame and the hydrogen flame are thus made to supplement one another in the same lamp in gas-testing.

The hydrogen is at present supplied from a small steel cylinder, 3 inches in diameter by 8 inches in length, and weighing 4 pounds. The cylinder when fully charged contains 4 cubic feet of hydrogen. This supply lasts for many tests, since when the flame is kept burning *continuously* at the ordinary height of 10 mm. it consumes only 1 cubic foot of gas in about four hours. A regulator may be adapted to the neck of the cylinder, but it has been found that a very delicate valve in the neck of the cylinder serves to adjust the stream of gas with ease without the intervention of any regulator.

The cylinder is slung in a leather case by a strap across the shoulder. A flexible tube from the nozzle of the bottle connects the

FIG. 1.



bottle with a little flanged metal nozzle: and this can be attached to an opening in the bottom or side of the oil reservoir of the lamp. The hydrogen is thus supplied to a copper tube of fine bore which passes through the reservoir and terminates on a level with, and close by, the top of the wick (fig. 1). Before the hydrogen is fed into the lamp, it is gently turned on and allowed to sweep the air out of the flexible tube; connexion is then made with the lamp, and by careful adjustment of the valve of the bottle the flame is made of the required size. The aperture in the lamp for introducing the hydrogen is closed by an automatic valve when the hydrogen is not in use.

Several series of measurements of "caps" were made over the hydrogen flame of this lamp in the testing chamber. The flame was adjusted to a height of 10 mm. by viewing it through a metal diaphragm containing a hole 10 mm. in diameter and held outside the lamp; or by making its tip level with the top of an upright wire fixed inside the lamp and near the burner. A glass cylinder of extra height (90 mm.) was fitted into the Ashworth lamp, and a dead-black background was produced by smoking a broad strip of the internal surface of the back of this glass with the flame of a wax taper. The blackened glass not only gave a surface against which pale caps were easily seen, but the dead surface prevented reflections giving perplexing ghosts of the true flame. The percentage of methane in the air in these experiments varied from 0.25 to 3, and the following heights of cap represent the average of a large number of fairly concordant readings:—

With 0.25 per cent. of methane, 17 mm. cap.

"	0.5	"	"	18	"
"	1.0	"	"	22	"
"	2.0	"	"	31	"
"	3.0	"	"	52	"

In the 3 per cent. mixture the tip of the cap disappeared in the opaque metal cylinder of the lamp above the glass. The hydrogen flame therefore became useless for measuring higher percentages, unless it was much reduced in size: but at this point the oil flame is competent to take up the indications with certainty. When very low proportions of gas are to be tested for, the size of the hydrogen flame may be increased with advantage, as is described below; but no observer could fail to see the smallest cap mentioned above as being produced by the 10 mm. flame.

The advantage which may be obtained by increasing the size of the hydrogen flame, when small percentages of gas are being looked for, is shown by the results of the following experiments, made by exposing the hydrogen safety-lamp in air containing 1 per cent. and 0.5 per

cent. of coal gas respectively: the height of the cap being noted in each mixture when the hydrogen flame was first 10 mm., and then 15 mm., in height.

	Flame 10 mm.	Flame 15 mm.
1 per cent. gas ....	27 mm. cap .....	50 mm. cap.
$0\frac{1}{2}$ „ ....	23 „ .....	38 „

Attention is directed in the above statement to the *height* of the cap alone, but, as a matter of fact, its change in general appearance is also very noticeable as the proportion of gas is increased. Very careful observation of the hydrogen flame in air free from gas serves to detect a slender and very pale cap. When the gas in the air reaches 0·25 per cent. the cap becomes broader and pale grey in colour, but is still indefinite in outline, especially at its summit, and is seen only *above* the hydrogen flame. As the proportion of gas increases, the flame becomes strikingly sharp and pointed in outline, distinctly bluish-grey in colour, and gradually broadens and extends down the sides of the hydrogen flame, finally enclosing it altogether and encircling the jet. At the same time, the hydrogen flame itself is constantly growing in every dimension, gaining in luminosity and acquiring a rose-red tip. It is well to have watched the above changes in the test-chamber, and to have become familiar with the appearance of the hydrogen flame in different percentages of gas before the flame is used for gas-testing.

The use of the hydrogen flame for gas-testing has the advantage of rendering possible the employment of a non-luminous flame which can be immediately adjusted to any convenient size: not only may the size of the cap be thus increased at will by enlarging the flame, but it is possible to avoid the risk of losing the flame in the lamp, which is incurred by drawing down the wick very low when an oil flame is made use of for gas-testing.

### III. “On the Application of the Safety-lamp to the Detection of Benzoline Vapour and other Inflammable Vapours in the Air.” By FRANK CLOWES, D.Sc. (Lond.), Professor of Chemistry, University College, Nottingham. Communicated by Professor ARMSTRONG, F.R.S. Received March 24, 1892.

Since the vapour of benzoline and of petroleum spirit, when mixed with air, may become dangerously explosive and inflammable, it is found necessary to employ safety-lamps instead of naked lights to illuminate spaces which may contain such a mixture. The safety-lamp should accordingly be used in the neighbourhood of the oil